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TRANSIT REFRIGERATION OF PERISHABLES IN OVERSEAS VAN CONTAINER SHIPMENTS

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ABSTRACT

Harris, C. M., and Hinds, R. H., Jr.

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Transit times for shipments of lettuce, oranges, and honeydew melons, made by ocean carrier from California to Japan and Hong Kong, were 10 and 15 days, respectively. Refrigerated van containers with constant air circulation through the load and a mechanism for reducing refrigeration capacity as the temperature approached the thermostat set point had an average temperature spread of only 2° Fahrenheit (1.1° Celsius) throughout the load from the second day of transit until arrival at destination ports. In two other refrigeration systems without these features, temperature variation throughout the loads averaged 4° F (2° C) and 10° F (6° C) during the same time period.

The carbon dioxide levels averaged about 2 percent in the two van loads of oranges and ranged from 0.5 to 1.5 percent in the remaining containers during shipment.

A van container designed to maintain controlled atmospheres during transit failed to hold the oxygen concentration at 5 percent, as intended.

Arrival quality of the lettuce and honeydew melons was impaired because of variation in maturity of individual heads or melons within cartons, which resulted in physical damage to the lettuce and an excessively wide range of degree of ripeness of the melons.

KEYWORDS: honeydew melons, oranges, lettuce, quality, controlled atmosphere, transit refrigeration.

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TRANSIT REFRIGERATION OF PERISHABLES IN OVERSEAS VAN CONTAINER SHIPMENTS

By C. Max Harris, *ARS plant physiologist*, and Russel H. Hinds, Jr., *ARS agricultural marketing specialist*

INTRODUCTION

Shipments of fresh fruits and vegetables in refrigerated vans by ocean carrier to Far Eastern markets have increased steadily during the last 10 years. Faster ships and better port facilities, which have reduced the transit time to cities such as Tokyo, Japan, and Hong Kong, have been a big factor in increasing the volume of perishables shipped to these areas. New, fast schedules have permitted ocean carriers to gradually change from shipping mostly frozen foods to shipping mostly fresh produce in refrigerated by van containers. In frozen food shipments, the main requirement of the refrigerated van is to keep the perimeter of the load at the desired temperature, usually around 0° Fahrenheit (−18° Celsius), and it is not important if the temperature drops below the thermostat set point. In loads of fresh produce, however, refrigeration requirements are much more critical. Temperatures higher than optimum cause the produce to deteriorate too rapidly, and temperatures that are too low cause it to be frozen or chilled. Fresh produce, being a living product, also produces heat from respiration. This heat, produced throughout the load, must be carried away by circulating air through the interior as well as around the perimeter of the load.

These test shipments were made (1) to evaluate three refrigeration systems used in van containers; (2) to evaluate load patterns for effects on product temperature; (3) to observe packaging, handling, and shipping techniques throughout the export marketing system; (4) to monitor oxygen (O_2) and carbon dioxide (CO_2) levels in test vans, including one van equipped with a controlled atmosphere system; (5) to evaluate commodity samples from test loads at origin and destination to determine the effects of transport on the market quality of the product; and (6) to make recommendations to improve handling methods and equipment used for exporting fresh fruits and vegetables to Far Eastern markets.

METHODS

All cargoes were stowed in an "air stack" loading pattern, which provides horizontal air channels throughout the load (figs. 1, 2, 3) to allow for good air circulation around the boxes of produce. Product temperatures were monitored by inserting thermocouples about 1 inch into the product at the 12 locations indicated in figure 4. Additional thermocouples were used to monitor temperatures at the air discharge, the return air duct, and under the floor. Plastic tubing was installed through the rear doors of each van to obtain atmosphere samples that were analyzed for O_2 and CO_2 levels. Atmospheres were measured daily, and temperatures were measured at least twice daily during transit, except at ocean carrier terminals when the vans were inaccessible.

Uniform test boxes of produce were assembled and examined at time of loading. Some of these boxes were placed at various positions in the test vans for examination at final destination. The remaining boxes were stored at U.S. Department of Agriculture laboratories in Fresno or River-

[1] Fresno, California.

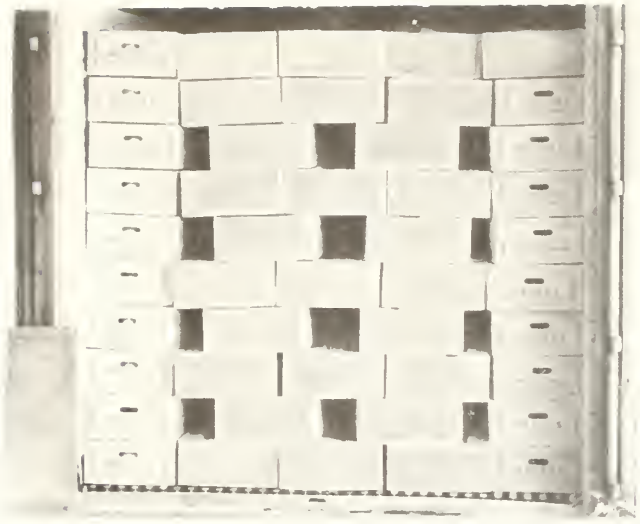

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FIGURE 1.—Honeydew melons in test van at Blythe, Calif., illustrating air-stack loading pattern.

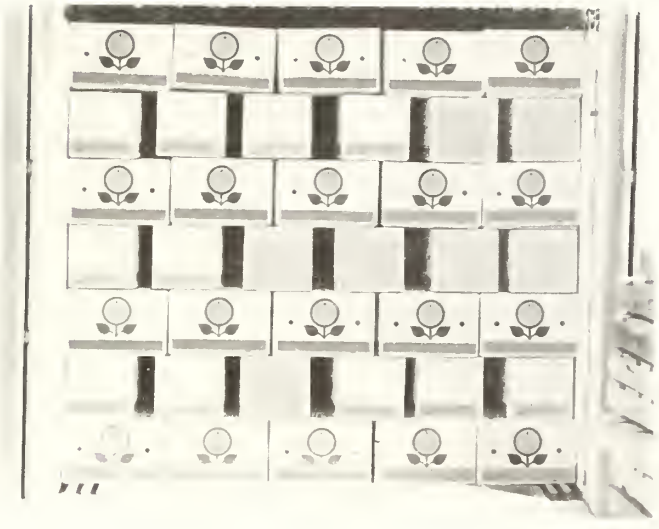

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FIGURE 2.—Oranges in test van at Irvine, Calif., showing air-stack loading pattern.

side, using the same temperatures as specified in the vans. The produce was examined after a time interval simulating export shipment.

Three types of refrigeration units were evaluated in this test. The older two units operate intermittently on demand from the thermostat, and the refrigeration units, rated at 30,000 Btu/hr (7,560 K cal/hr),[2] operate at full capacity

[2] All ratings are approximate and were made with a 35° F (2° C) load and a 100° F (38° C) ambient temperature.

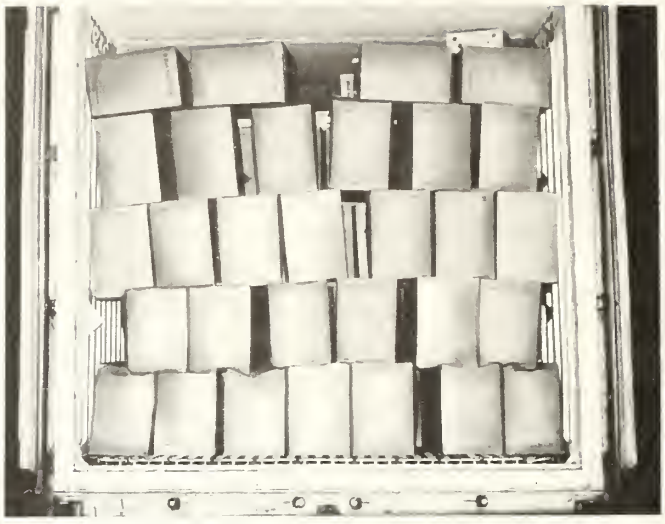

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FIGURE 3.—Lettuce loaded at Salinas, Calif., in air-stack pattern.

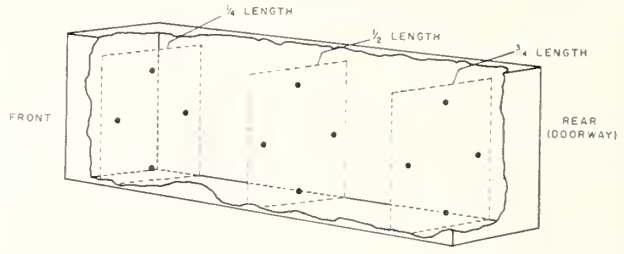

FIGURE 4.—Position of thermocouple sensing points in produce of each test load.

during the "on" cycle and are coupled with the evaporator fan. When the set point has been reached and the unit is in the "off" cycle, both the compressor and the evaporator fan stop, and no air circulates inside the cargo area. The principal difference between the two older units is that the No. 1 unit may run until its coil temperature is 18° F (10° C) below the set point before shutting off, whereas the comparable limit for the No. 2 unit is 12° F (7° C).

In the newest unit tested (No. 3), the compressor also operated intermittently on demand from the thermostat. However, the refrigeration capacity, which is rated at 31,000 Btu/hr (7,800 K cal/hr), is reduced to 18,500 Btu/hr (4,700 K cal/hr) when the temperature inside the van is lowered to 7° F (4° C) above the termostat set point, and the evaporator fan operates continuously, even during the "off" cycle of the compressor.

Interior dimensions of all van containers were 32 by 7.3 by 7.3 feet (9.9 by 2.3 by 2.3 meters), and all walls had 3 inches (8 cm) of polyurethane insulation.

The design of the air circulation system was similar in all vans tested. Cold air was delivered to the rear of the vans via a ceiling duct that extended from the evaporator coil in the front to within 6 ft of the rear doorway. The air then passed from the rear, through the horizontal channels in the load, to a return air bulkhead located in the lower half of the front wall. The inside surfaces of the walls and the floor were ribbed to permit air circulation around the load.

The two vans of honeydew melons were loaded in Blythe, Calif., on June 18, 1974, and were transported by truck to Long Beach, Calif., where they were transferred to the container ship on June 20. Melons loaded in the van with a No. 1 type refrigeration unit were not precooled and were shipped to Tokyo. The other load was partially precooled before loading into a van with the No. 3 type refrigeration unit; this load was shipped to Hong Kong.

The two vans of oranges were loaded in Irvine, Calif., on June 19 and were delivered to Long Beach by truck. The oranges placed in a van with a No. 2 type of refrigeration unit averaged 71° F (22° C) at loading, and those placed in a van with a No. 3 type unit averaged 67° F (19° C).

The two vans of wrapped lettuce were vacuum cooled and loaded in Salinas, Calif., on June 20. They were hauled over the highway to Oakland, Calif., where they were transferred to the container ship on June 21. Both vans had No. 3 type refrigeration units, but one van was designed for maintaining a controlled atmosphere (CA) and the other was not. The CA van had an initial atmosphere with 5.0 percent O_2 and approximately 95 percent nitrogen.

General condition of the cargo in the test vans was observed during unloading at destination cities, and the sample cartons of produce were recovered for quality evaluation.

RESULTS

Transit Temperatures

HONEYDEW MELONS

Initial temperatures of nonprecooled melons shipped in the No. 1 type van averaged 93° F (34° C) and ranged from 88° F (31° C) to 97° F (36° C) (fig. 5). The average melon temperature in this load reached 50° F (10° C) after 2 days, but the temperatures ranged from 41° F (5° C) to 58° F (14° C). The average load temperature was slowly reduced to about 44° F (7° C) by lowering the thermostat from the initial setting of 44° F (7° C) to 39° F (4° C). The temperature spread throughout the load, however, remained about 10° F (6 C°) for the rest of the trip to Yokohama, Japan.

The partly precooled melons shipped in the No. 3 type refrigerated van averaged about 65° F (18° C) initially and had temperatures ranging from 54° F (12° C) to 74° F (23° C) (fig. 6). Average temperature of the load was reduced to 44° F (7° C) after 2 days, and temperatures ranged from 36° F (2° C) to 53° F (12° C). The refrigeration unit on this van was off on the sixth day and the eighth day due to a malfunction; after this period, the unit ran normally and temperature variation within the load was only 2° or 3° F (1° or 2° C) for the remainder of the trip.

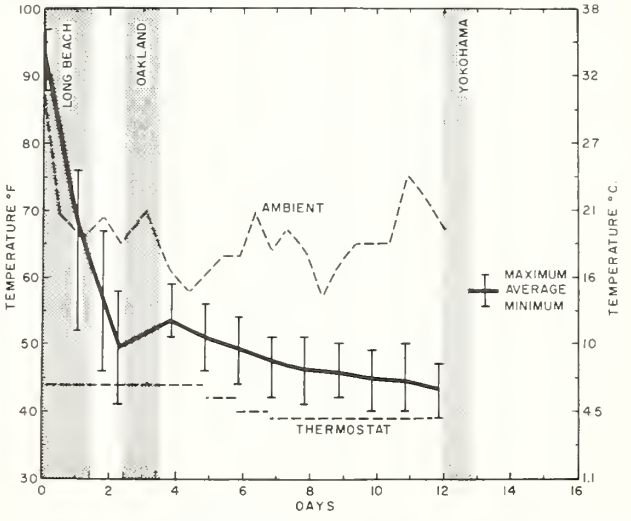

FIGURE 5.—Temperatures of honeydew melons shipped from California to Yokohama, Japan, in No. 1 type refrigeration van.

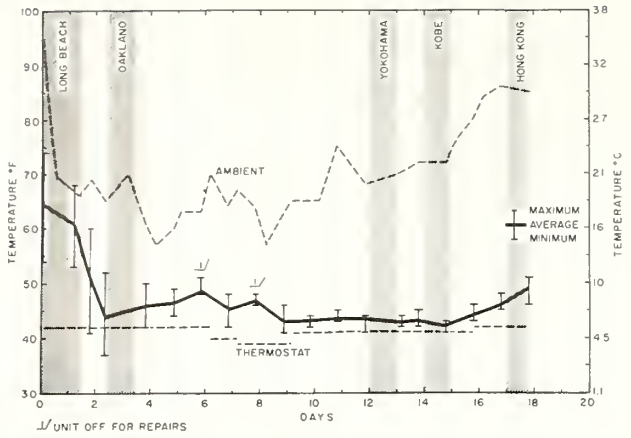

FIGURE 6.—Temperatures of honeydew melons shipped from California to Hong Kong in No. 3 type refrigeration van.

ORANGES

Oranges shipped in the No. 2 type refrigerated van were 71° F (22° C) at loading and averaged 44° F (7° C) on the fourth day, with a range of 4° F (2° C) (fig. 7). The average load temperature slowly approached the thermostat set point of 40° F (4° C) during the rest of the voyage, and the range remained 4° F (2° C) to 6° F (3° C). Fruit temperatures in the coldest locations dropped 1° F (0.5° C) to 3° F (2° C) below the thermostat set point in this van during the last 7 days of transit.

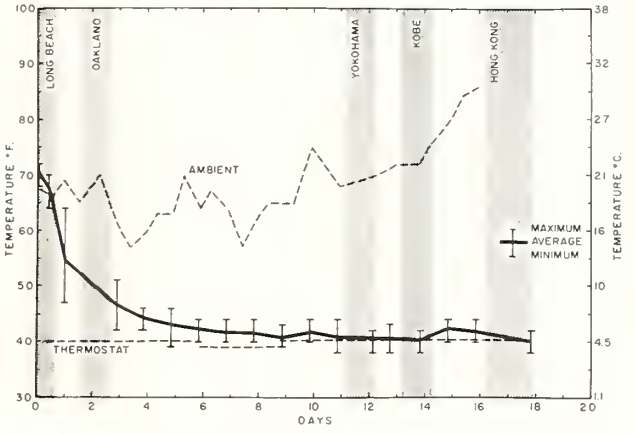

FIGURE 7.—Temperatures of oranges shipped from California to Hong Kong in a No. 2 type refrigeration van.

Oranges shipped in the No. 3 type van averaged 67° F (19° C) initially (fig. 8). The thermostat was set at 44° F (7° C) during the first 3 days of transit during which average commodity temperature was reduced to 45° F (7° C), with a range of 5° F (3° C). The thermostat was subsequently lowered to 40° F (4° C), and average fruit temperature stayed slightly above this temperature. The range in the load was about 2° F (1° C) during the remainder of the voyage.

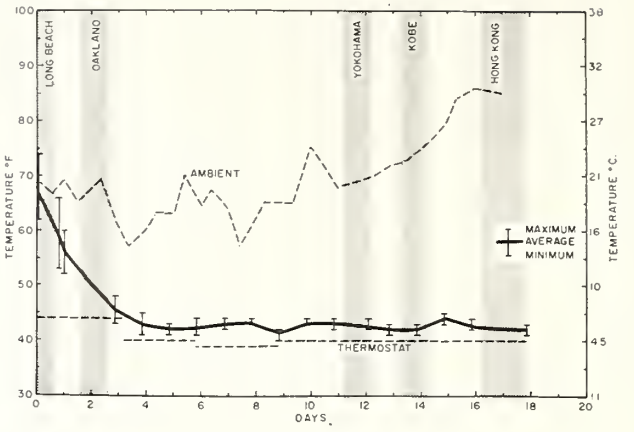

FIGURE 8.—Temperatures of oranges shipped from California to Hong Kong in a No. 3 type refrigerated van.

LETTUCE

Both loads of lettuce were precooled to about 33° F (0.5° C) before loading. Average temperatures of both loads were about 2° F (1° C) above the 34° F (1° C) thermostat setting during the voyage (figs. 9 and 10). Temperature variation of the lettuce was 3° F (2° C) or less in both vans during most of the transit period.

The portions of the loads that cooled most

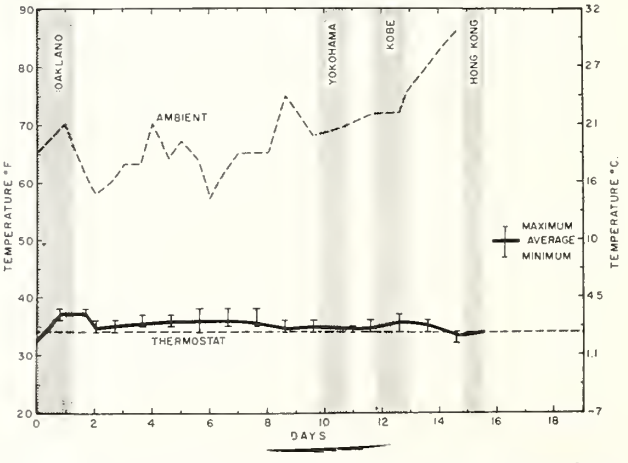

FIGURE 9.—Temperature of lettuce shipped from California to Hong Kong in a No. 3 type refrigerated van equipped with controlled atmosphere capability.

slowly were similar in all test vans and are best illustrated by the two vans of melons (figs. 11 and 12). Although they are not directly comparable

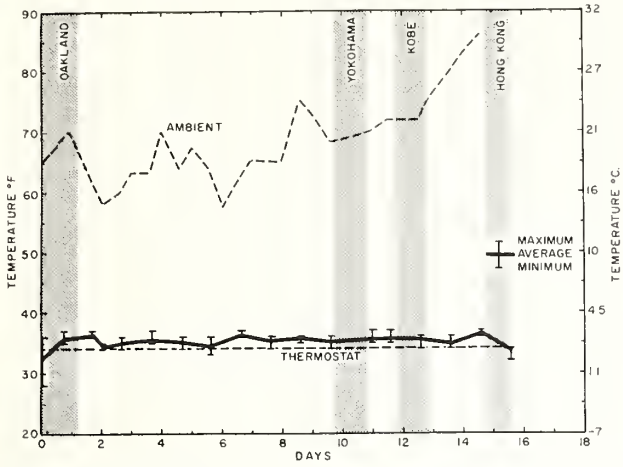

FIGURE 10.—Temperature of lettuce shipped from California to Hong Kong in a No. 3 type refrigerated van.

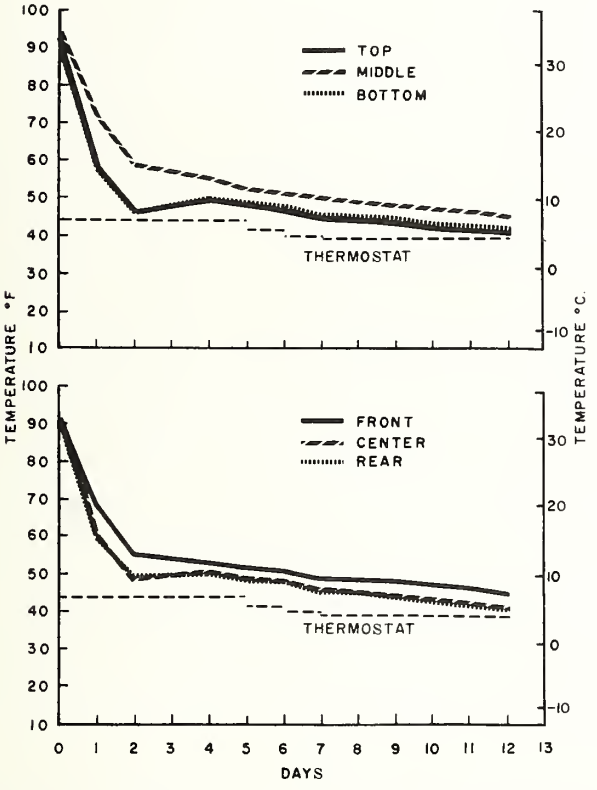

FIGURE 11.—Cooling curves for honeydew melons shipped in a No. 1 type refrigerated van. *Top:* Averages by layer, regardless of lengthwise position. *Bottom:* Averages by lengthwise position, regardless of layer. (See also fig. 4.)

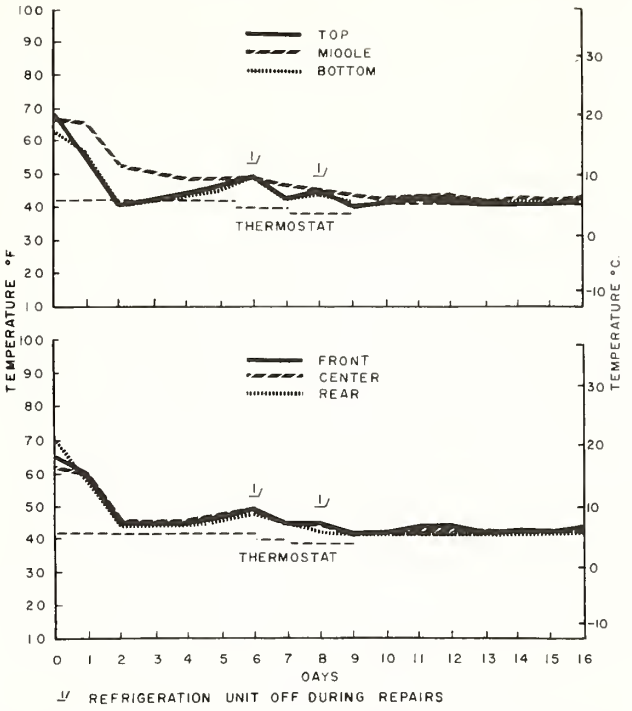

FIGURE 12.—Cooling curves for honeydew melons shipped in a No. 3 type refrigerated van. *Top:* Averages by layer, regardless of lengthwise position. *Bottom:* Averages by lengthwise position, regardless of layer. (See also fig. 4.)

because of differences in initial temperature, transit time, and mechanical failures, both loads cooled more slowly in the middle than in the top or bottom layer. In addition, the No. 1 van cooled more slowly in the front than in the center or rear of the load. Temperature differences in the No. 1 type van (fig. 11) were much greater than in either of the other types of van. The average transit temperature for the middle layer of this van was 56° F (13° C), while the top and bottom layers averaged about 50° F (10° C) for the trip (fig. 11). Temperatures at the front quarter-length averaged about 54° F (11° C) and 50° F (10°), respectively.

The average transit temperature for the middle layer of the No. 3 type melon van was 48° F (9° C) and 45° F (7° C) for the top and bottom layers (fig. 12). Temperature differences from front to rear were insignificant in this van.

Atmospheres in Transit

The O_2 level in the CA van was 5 percent initially and remained at this level until the fourth

day, when it began to rise slowly. O_2 concentrations from the sixth through the tenth day were 7.5, 10.5, 12.0, 14.0, and 16.0 percent, respectively. O_2 concentration was 18 percent at destination (table 1). O_2 levels remained near normal (20.6 percent) in the remaining test vans.

The CO_2 level averaged about 1.5 percent in the CA van and less than 1 percent in the other lettuce van during transit (table 1). CO_2 accumulations were low in the honeydew melon vans, averaging about 0.5 percent in the oldest (No. 1) van and 1 percent in the newer (No. 2) van. The highest CO_2 levels were found in the two van loads of oranges, both of which averaged about 2 percent CO_2 during transit.

Quality Evaluations

HONEYDEW MELONS

Both loads of melons arrived in generally good condition. No mold or decay was found on any melons examined. In the No. 1 type van shipped to Japan, eight melons in the rear doorway area showed chilling injury. This was the coldest area in the loads because it was immediately below the air discharge duct.

Melons in the No. 1 van ripened about 1.5 times faster during shipment than melons in the No. 3 van (table 2). The melons ripened faster in the No. 1 van because of their higher initial and transit temperatures. Melons were rated for maturity by the method published by Kasmire et al.[3]

Melons stored at the laboratory, under conditions simulating export shipments to Japan, ripened about three times faster at 50° F (10° C) than at 41° F (5° C) (table 3). However, melons of maturity class 1, ripened very little after 14 days storage and even after 20 days were of poor quality.

Melons shipped to Tokyo ripened at about the same rate as those held 14 days at 50° F (10° C) in the laboratory, whereas melons shipped to

[3] KASMIRE, R. F., H. K. PRATT, and F. CHACON. HONEYDEW MELON MATURITY AND RIPENING GUIDE. Univ. Calif. Agr. Ext. Serv. MA-26, 3 pp. 1970.

TABLE 1.—*Concentrations of carbon dioxide (CO_2) and oxygen (O_2) in test vans during transit, 1974*

Days in transit	Location	Lettuce [1]				Honeydew melons				Oranges			
		Controlled atmospheres [2]		Normal air		No. 1 type van [3]		No. 3 type van		No. 2 type van		No. 3 type van	
		CO_2	O_2	CO_2	O_2	CO_2	O_2	CO_2	O_2	CO_2	O_2	CO_2	O_2
		Percent											
0	Arr. Oakland												
1	Lv. Oakland	0.5	5.0	0	20.0	0	20.0	1.0	20.0	1.5	19.0	3.5	17.0
2		1.5	5.5	.5	20.5	.5	20.5	2.5	20.0	2.0	20.5	3.0	19.5
3		.5	4.5	0	20.5	.5	---	1.5	20.0	1.0	---	1.5	---
4		1.0	7.5	.5	---	0	20.5	1.5	---	2.5	---	2.0	---
5		1.0	10.5	.5	20.0	.5	---	1.0	20.0	1.0	20.5	2.0	20.0
6		1.0	12.0	.5	---	.5	20.5	1.0	---	1.5	---	1.5	---
7		1.0	14.0	.5	20.5	.5	---	1.0	20.0	2.0	---	2.0	---
8		1.0	16.0	1.0	20.0	.5	20.5	1.0	---	2.0	---	2.0	---
9	Arr. Yokohama	1.5	16.0	.5	---	.5	20.5	1.0	20.0	2.0	20.0	2.0	20.0
10	Lv. Yokohoma												
	Arr. Kobe	--	---	--	---			--	---	---	---	--	---
11	Lv. Koke	1.5	16.5	.5	20.0			1.0	20.0	---	---	--	---
12		2.5	17.0	1.0	---			1.0	---	3.0	---	2.0	---
13		--	---	--	---			--	---	---	---	--	---
14	Arr. Hong Kong	2.5	18.0	1.0	---			1.0	20.0	2.5	20.5	2.5	20.0

[1] Type No. 3 refrigerated van.
[2] CA unit failed on day 4.
[3] Unloaded at Yokohama.

Hong Kong ripened at about the rate of melons held in the laboratory 20 days at 41° F (5° C) (tables 2, 3).

ORANGES

Both vans of oranges arrived in good condition. Decay averaged 1.5 percent, and rind injury aver-

TABLE 2.—*Increase in ripeness of honeydew melons during shipment to Tokyo and Hong Kong*

Destination and transit conditions	Initial maturity: Maturity class [1]	Initial maturity: No. of melons in each class	Maturity at destination: Maturity class [1]	Maturity at destination: No. of melons in each class	Average maturity class change (steps)	Average change in maturity class per day
Tokyo shipment, Van type No. 1 Transit time: 16 days Transit temp: mean high 58° F (14° C) mean low 47° F (8° C) overall mean 53° F (12° C)	1	15	1	7	0.74	0.046
			1–2	8		
	1–2	30	1–2	13		
			2	14		
			3	3		
	2	15	2	1		
			3	12		
			4	2		
	3	1	4	1		
Hong Kong shipment, Van type No. 3 Transit time: 19 days Transit temp: mean high 50° F (10° C) mean low 44° F (7° C) overall mean 47° F (8° C)	1	5	1	3	0.60	0.031
			1–2	2		
	1–2	16	1–2	6		
			2	9		
			3	1		
	2	8	2	4		
			3	4		
	3	1	4	1		

[1] 0=immature; 1=mature, but unripe; 1–2=fully mature; 2=ripening initiated; 3=ripe; 4=overripe; 5=ripe and soft. No melons were in class 0, 4, or 5 initially. (See reference [2].)

TABLE 3.—*Maturity of honeydew melons in laboratory storage tests simulating shipments to Tokyo and Hong Kong*

Storage duration and temperature			Proportion of melons in each maturity class: Initially					Proportion of melons in each maturity class: After storage					Average maturity during storage	Average maturity change per day
			1	1–2	2	3	4[1]	1	1–2	2	3	4[1]		
Days	*° F*	*(° C)*	*Percent*					*Percent*					*Steps*	*Steps*
14	41	(5)	6	39	39	6	11	6	28	44	11	11	0.2	0.014
14	50	(10)	17	67	11	6	--	6	50	28	11	11	.6	.043
20	41	(5)	13	67	20	--	--	--	33	53	13	--	.7	.035
20	50	(10)	13	33	47	7	--	--	13	40	33	13	1.0	.05

[1] 0=immature; 1=mature but unripe; 1–2=fully mature; 2=ripening initiated; 3=ripe; 4=overripe; 5=ripe and soft.

aged less than 1.0 percent in both loads (table 4). Crushing damage, which resulted in misshapen fruit, occurred primarily in the middle and bottom layers of the loads (table 4) and averaged 8.5 percent in both loads.

Samples of the test oranges held at the Riverside Laboratory and examined after simulated transit times (18 days) and temperatures (41° and 50° F) (5° and 10° C) had about the same kind and amount of defects as the fruit shipped to Hong Kong (table 4). Rind injury, a symptom of chilling in oranges, was greater in fruit stored at 41° F (5° C) than fruit held at 50° F (10° C). The reverse was true for the number of decayed fruit found after storage.

TABLE 4.—*Defects of oranges after shipment from California to Hong Kong and after laboratory storage simulating export*

Holding conditions	Decay	Rind injury	Misshapen fruit
	Percent	*Percent*	*Percent*
No. 2 van			
Top layer	1.1	0	2.3
Middle layer	2.4	1.2	5.9
Bottom layer	1.1	.9	20.3
Mean	1.5	.7	9.5
No. 3 van			
Top layer	0	.9	1.8
Middle layer	2.6	0	10.6
Bottom layer	2.0	1.7	10.4
Mean	1.5	.9	8.9
Laboratory			
18 days at 41° F (5° C)	.3	3.6	6.0
18 days at 50° F (10° C)	2.1	0	4.3

LETTUCE

Differences in arrival quality in the loads of lettuce cannot be attributed to CA treatment because of the failure of that system during transit. Decay was the most serious defect occurring in both loads and was found in about 17 and 25 percent of the heads from the CA van and air van, respectively (table 5). In most cases, the decay covered only a small area and could be removed by trimming. Crushing damage was also widespread in both samples of lettuce. Most of this damage occurred during packing at origin when a hard head was pushed into a softer adjacent head.

TABLE 5.—*Overall quality, decay, and crushing or bruising injury of lettuce after shipment from California to Hong Kong and after laboratory storage simulating export*

Holding conditions	Average overall quality	Decay		Crushing and bruising injury	
		Heads affected	Average severity of affected heads	Heads affected	Average severity of affected heads
	Rating [1]	*Percent*	*Rating* [2]	*Percent*	*Rating* [2]
Normal air, type No. 3 van.	5.0	25	5.0	100	5.3
Low oxygen, type No. 3 van.[3]	5.2	17	4.5	58	5.3
Laboratory holding test:					
17 days in air at 38° F (3° C)	6.7	17	4.0	---	---

[1] 9=excellent; 7=good; 5=fair; 3=poor; 1=not usable.

[2] 1=none; 3=slight; 5=moderate; 7=severe; 9=extreme (not usable).

[3] Low oxygen van did not maintain atmosphere during entire transit period.

DISCUSSION

The most important variable of those tested in these experimental shipments was the type of refrigeration system used on the van containers. The van equipped with the No. 3 type refrigeration system was superior to the others because it maintained produce loads at temperatures near the set point and minimized temperature variation within the load. This type of van is superior mainly because the refrigeration capacity is reduced as the temperature inside the van approaches the thermostat set point and because the evaporator fan operates continually. These innovations help eliminate low temperature override in the discharge airstream just before the thermostat is satisfied. In the older units, this override can produce temperatures that are 10° to 15° F (6° to 8° C) lower than the thermostat set point and can be the cause of freezing or chilling injury to some loads. The continual fan operation in the new unit also eliminated long periods without air circulation in the cargo area that tend to increase temperature variation within the load. After the second day in transit, the average temperature spread in units operating normally was about 2° F (1° C) in all test loads transported in No. 3 type vans, about 5° F (3° C) in No. 2 type vans, and 10° F (6° C) in the No. 1 type van. These temperature ranges, however, are also affected by differences in the initial commodity temperatures when the vans were loaded.

Handling all containers by the ocean carrier was very efficient from shipping point to destination ports. Time spent in loading-reloading operations was 24 hours or less in all ports visited, and total transit time from Oakland to Hong Kong was 15 days. The total time for marketing is sometimes increased, however, because receivers may not take delivery of the load from the container terminal until 1 to 5 days from arrival, depending on local market conditions and the perishability of the product.

The quality of all produce tested was generally good. However, the arrival condition of the honeydew melons and lettuce could be improved by more careful segregation with respect to maturity at shipping point. Honeydew melons, harvested at ripeness class 1, will not ripen satisfactorily without ethylene gassing, but if shipped after ripening has been initiated (stage 2 and above), they may be overripe after a long transit period. The riper melons should be shipped to local markets where they can be used more quickly. Immature melons and class 1 melons that have not been gassed should not be shipped at all.

Soft, immature heads of lettuce are often damaged when packed in cartons with hard, overmature heads. Much of this crushing and bruising damage could be eliminated by reasonably careful selection of heads of proper size and maturity during harvest.

In consideration of the expense incurred in growing, harvesting, packing, and shipping produce to foreign markets, only the highest quality produce should be exported, and every precaution should be taken to retain that quality during shipping and marketing.

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